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HIGHWAY RESEARCH REPORT

BIASED AND RANDOM SAMPLING

FINAL REPORT

STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
-- ARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

TRANSPORTATION LABORATORY

RESEARCH REPORT

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16. ABSTRACT
This study is an investigation of the principle of random sampling involved in determining percent relative compaction when using a statistical area concept method.
The data were collected from three projects and indicated that there is no difference between the average relative compaction of an area where test sites were selected using a random plan and without using a random plan. On a fourth project, differences were noted when sites were selected in a biased manner.
It was concluded that use of a modified random sampling plan was desirable. A system for using a random sampling plan is presented.

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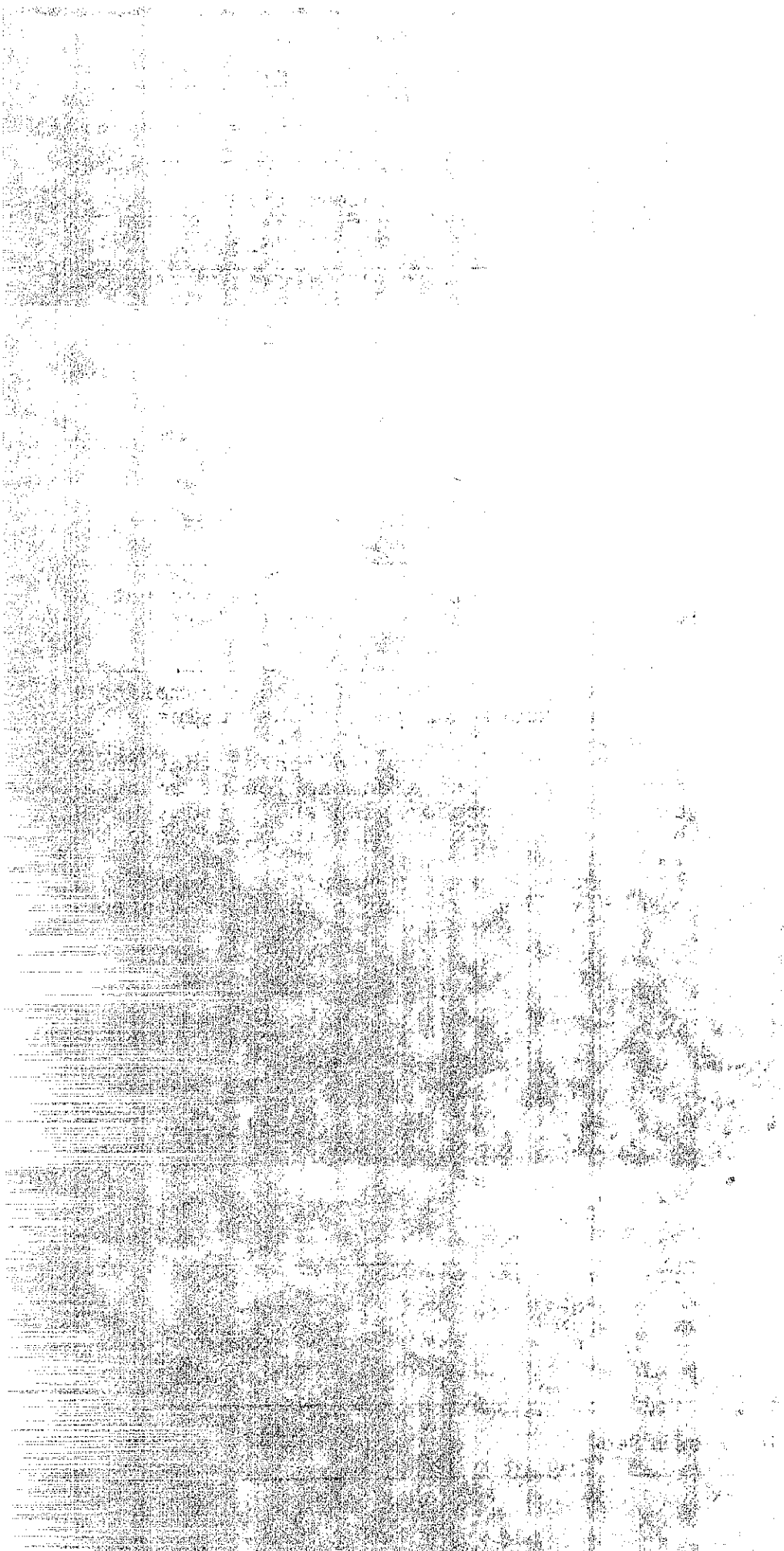

STATE OF CALIFORNIA—BUSINESS AND TRANSPORTATION AGENCY RONALD REAGAN, Governor

DEPARTMENT OF TRANSPORTATION
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Trans. Lab No. 632305
Fed. No. F-1-5
September 1973

Mr. R. J. Datel
State Highway Engineer

Dear Sir:

Submitted herewith is the final research report titled:

BIASED AND RANDOM SAMPLING

by

Mas Hatano and Martin Nolan
Co-Investigators

Albin D. Hirsch, P.E.
Principal Investigator

Under the supervision of

Raymond A. Forsyth, P.E.

Very truly yours,

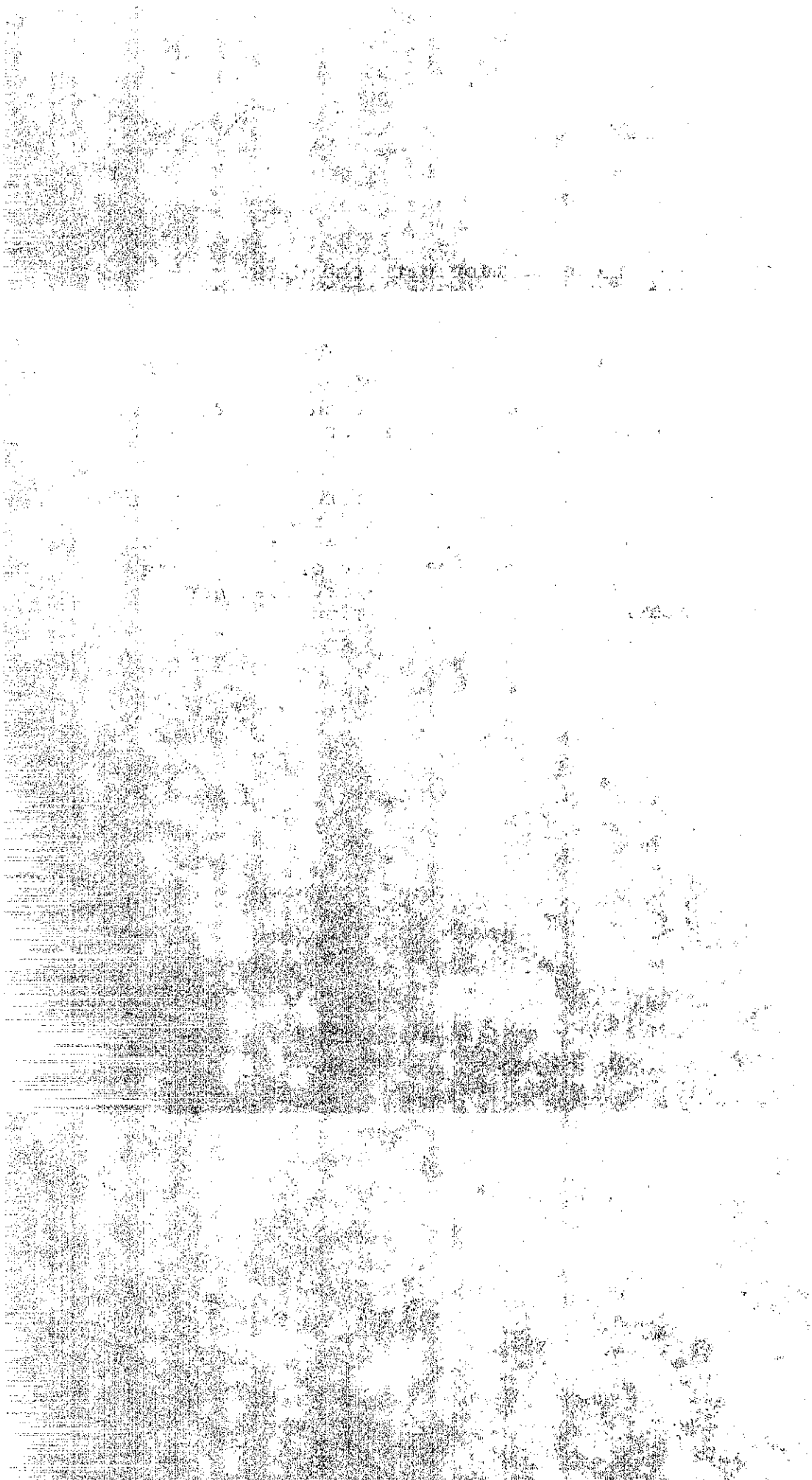
JOHN L. BEATON
Laboratory Director

ACKNOWLEDGEMENT

This project was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration, under agreement No. F-1-5.

The authors wish to express their appreciation to the Construction Departments of Districts 01, 10, 04 and 11 for their cooperation in permitting tests to be made on projects in their districts. Particular recognition is extended to the Resident Engineers and their staffs on the various projects.

The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.



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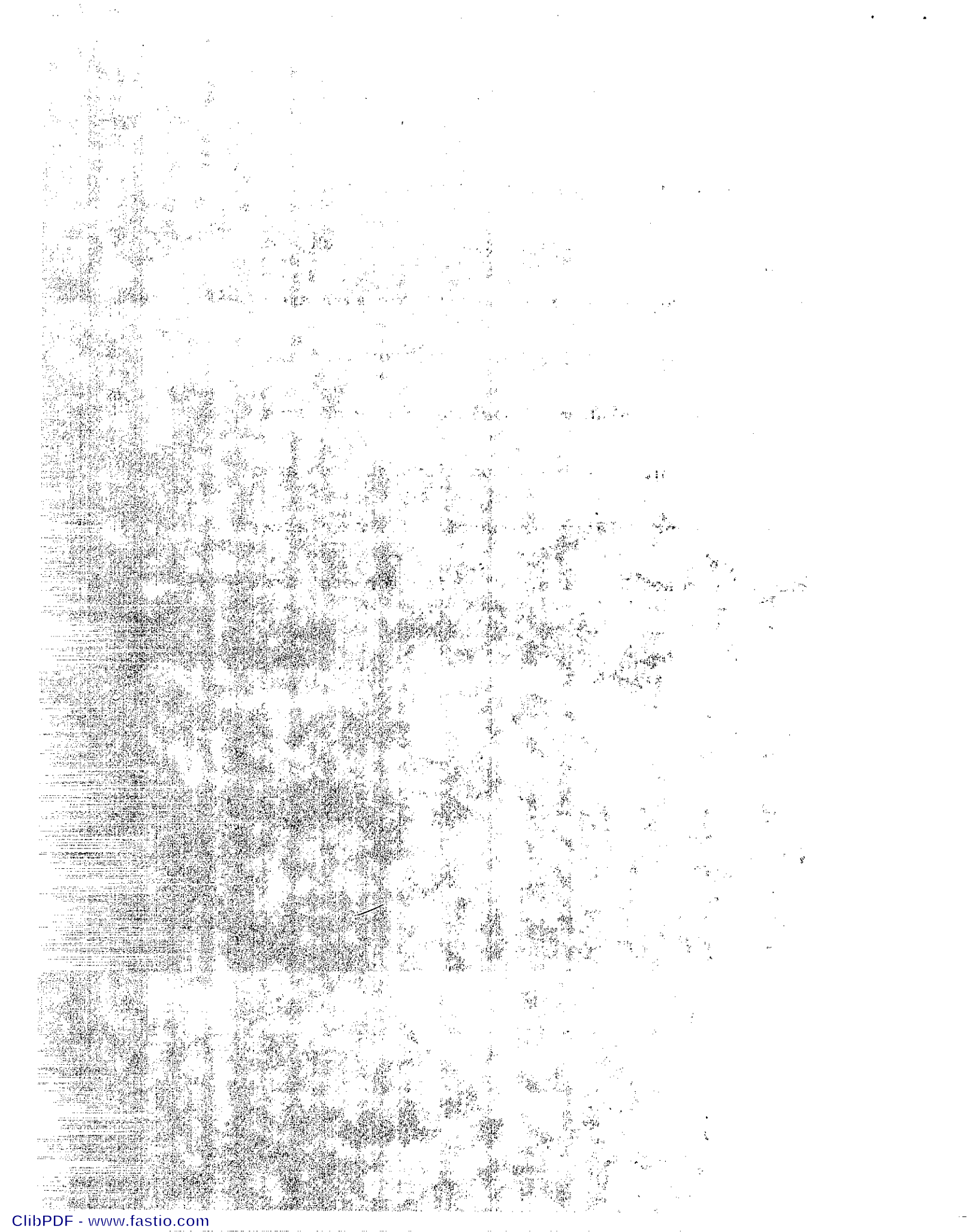


INTRODUCTION

The California Transportation Laboratory test procedure for compaction control of earthwork is based on statistical concepts. An area of work is selected based on uniformity of factors affecting compaction. Insofar as possible, the area designated shall be generally homogeneous for both character of material and conditions of production and compaction. The size of area may be limited, such as structure backfill, or be more than half a mile of roadway.

After an area is established, the testor must randomly select a minimum of 3 to 6 test sites depending on the size of area. The measurements from the test sites are averaged and related to a composite test maximum density to determine percent relative compaction. This is a statistical approach whereby a limited number of tests are averaged to approximate the theoretical average that would be obtained if a large number of tests were made in the area.

Statisticians indicate a statistical approach is not valid unless random samples are obtained. The California Transportation Laboratory Test Method No. Calif. 231E* states that random samples shall be taken but it provides no means for accomplishing this.

Some engineers feel that a random sampling plan should be in the procedure while others feel it is not necessary.

* Test Method No. Calif. 231E, State of California, Department of Transportation, Transportation Laboratory, Materials Manual of Testing and Control Procedures, Vol. I.

DEFINITIONS

In order to clarify some of the terms used in this report, a list of words with their definitions as used in this report is given.

random sample - A sample selected in a manner so that every part of the population being sampled has an equal chance of being included. Also, the selection of one sample must be independent of the selection of any other sample.

non-biased sample - A sample selected on the basis of a modified random sampling plan.

selective sampling - Selecting a sample with the intent of purposely omitting or including certain parts of the population being sampled.

non-random sample - Samples obtained by using a fixed sampling pattern.

OBJECTIVES

1. Determine if there is any significant difference between the average values obtained by using non-biased, non-random and selective sampling plans.

2. If it is shown that a random sampling plan is needed, finalize a random procedure for selecting test sites in an area.

CONCLUSIONS

1. There was no significant difference between average test results from an area determined by using a non-biased sampling plan and average test results from the same area using a non-random sampling plan.

2. There was a significant difference between average test results from an area determined by using a non-biased sampling plan and average test results from the same area when using a selective sampling procedure.

IMPLEMENTATION

The results of this study have been incorporated in Test Method 231-F* dated April 2, 1973, "Method of Test for Relative Compaction of Untreated and Treated Soils and aggregates by the Area Concept Utilizing Nuclear Gages". Appendix I shows the procedure used to select random test sites.

This report will be forwarded to the Construction Branch so that they may consider modifying their construction manual to reflect changes already made in Test Method No. Calif. 231-F.

COST SAVINGS

The direct benefit derived from the research is the improvement of test procedures to obtain more consistently competent results.

There will be other benefits such as better contractor relationship since the site selection process will not be influenced by any individual's judgment.

This procedure will eliminate the possibility of selective sampling and could minimize possible contractor claims.

PROCEDURE

A modified statistical procedure for selecting test sites in an area was developed. It consisted of using a set of random numbers to locate 10 spots on a gridded sheet. Ten different sheets of non-biased sample plans were made. The operator would select one of the plans based on the nuclear gage standard count. Any number of tests (up to 10) are performed at the approximate locations on the grade represented by the spots on the non-biased sample plan.

The details of the system called "Non-biased Sample Plans" are shown in Appendix I.

Three ongoing construction projects were used to obtain comparative tests. After an area was determined, test sites were selected using the non-biased sample plans. An equal number of test sites in the same area were selected in a manner commonly used by gage operators. Usually, this resulted in taking a series of sites in a row down the middle of the area, diagonally across the area or in some other generally fixed pattern. (Non-random sample)

* Test Method No. Calif. 231F State of California, Department of Transportation, Transportation Laboratory, Materials Manual of Testing and Control Procedures, Vol. I.

On a fourth construction project, test sites in an area were initially selected using the non-biased sample plans. A second series of test sites were selected along the edges of fill and other spot locations which could have had poor compaction. The comparison intended in this case was between sites determined by a non-biased method and by a selective sampling procedure.

All testing performed for this study was done with a Portaprobe Nuclear gage using the 8 inch direct transmission mode. The gage was calibrated using the California Transportation Laboratory standard blocks. The procedure used is outlined in Test Method No. Calif. 911B*.

DESCRIPTION OF PROJECTS

Project L

This project is located in Lake County, California. The construction consists of building a 4-lane freeway 9.5 miles in length around the town of Lakeport, California. The terrain is hilly and the land is used for grazing and orchards. The material was mostly silty-clays and gravels.

Project C

This project is located in Calaveras County, California. The 8.6 mile job lies between the Stanislaus County line and the town of Copperopolis, California. The construction consists of building a 2-lane highway traversing the Sierra Foothills. The material is quite varied ranging from silts and clays to shales and hard massive rock formations which had to be blasted to be removed.

Project SM

This project is located along the Crystal Springs reservoir in San Mateo County, California. The construction consists of building an 8-lane split level freeway and a major interchange between routes 280 and 92. Total length of major construction was 3.3 miles. The terrain is hilly and the material was somewhat varied, being either a silty, sandy clay with rock fragments or decomposed serpentine rock fragments.

Project SD

This project is in San Diego County near Chula Vista, California. The construction consists of building about 3.2 miles of 8-lane freeway surfaced with portland cement concrete. The road traverses rolling hills with the highest fill being around 70 feet high. Tests were performed on a mixture of clay and sands with some gravel.

* Test Method No. Calif. 911B. State of California, Department of Transportation, Transportation Laboratory, Materials Manual of Testing and Control Procedures, Vol. III.

DISCUSSION

All tests on the four projects in this study were performed on embankment material. Establishment of the test area was based on uniformity of factors such as homogeneity for character of material and conditions of production and compaction. All in-place measurements made with a nuclear gage were averaged and related to a composite test maximum density to determine an average percent relative compaction for the area.

Project L

Six test sites in each area were selected using a non-biased sample plan. In the same area, six additional test sites were selected in a line along the centerline of the fill to represent the non-random condition. This pattern was repeated on 10 test areas. In each area an average percent relative compaction was calculated for the two procedures. The data is shown on Figure 1.

The average percent relative compaction values between the two methods of site selection for Project L are generally the same.

Figure 2 shows the range of test values within each area. The dispersion of test results in each area between the two methods of site selection are generally the same.

Project C

Six test sites in each area were selected using a non-biased sample plan. In the same area, six additional test sites were selected in a line diagonally across the fill to represent the non-random condition. This pattern was repeated on 9 test areas. The same calculations for average percent relative compaction were made as described for Project L. The data is shown on Figure 3.

The average percent relative compaction values between the two methods of site selection for Project C are generally the same.

Figure 4 shows the range of test values within each area. The dispersion of test results in each area between the two methods of site selection are generally the same.

Project SM

Five test sites in each area were selected using a non-biased sample plan. Five test sites instead of six were used on this project due to a change in test procedure. In the same area, five additional test sites were selected by dividing the generally rectangular area into five equal parts and taking a test in the middle of each part to represent the non-random condition. This pattern was repeated on 10 test areas. The same calculations for average percent relative compaction were made as described for Project L. The data is shown on Figure 5.

The average percent relative compaction values between the two methods of site selection for Project SM are generally the same.

Figure 6 shows the range of test values within each area. The dispersion of test results between the two methods of site selection are generally the same.

Project SD

Five test sites in each area were selected using a non-biased sample plan. In the same areas, five additional test sites per area were determined by selective sampling. A deliberate attempt was made to pick isolated sites that appeared to have less compaction than the area as a whole. This pattern was used on 5 test areas. The same calculations for average percent relative compaction were made as described for Project L. The data is shown on Figure 7.

The average percent relative compaction for the sites selected using the non-biased sampling plan was higher than the average for the sites using selective sampling. This indicates that a test operator could obtain lower test results by selective sampling. Conversely, it appears that he could also obtain higher test results by selective sampling.

Sherman, Watkins and Prysock* reported that selective sampling and resampling resulted in higher percent relative compactions as compared to tests obtained by random sampling. These tests were performed using the sand volume method.

Figure 8 shows the range of test values within each area. The dispersion of test results between the two methods of site selection are generally the same.

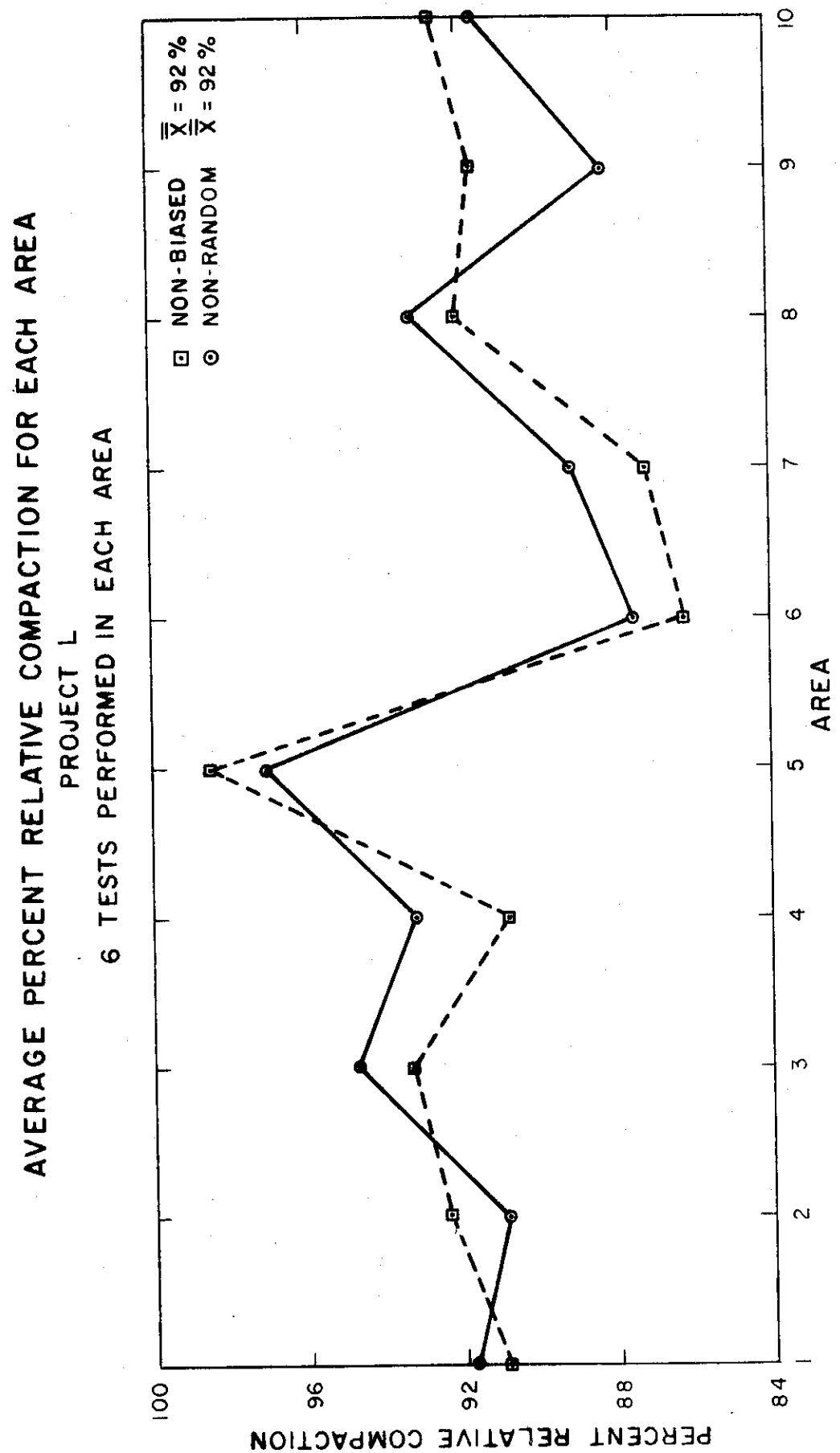
The test data from this study indicates that there is no significant difference between test sites selected using a non-biased sampling procedure as compared to a non-random sample procedure as long as there is no deliberate attempt to select good or bad sites.

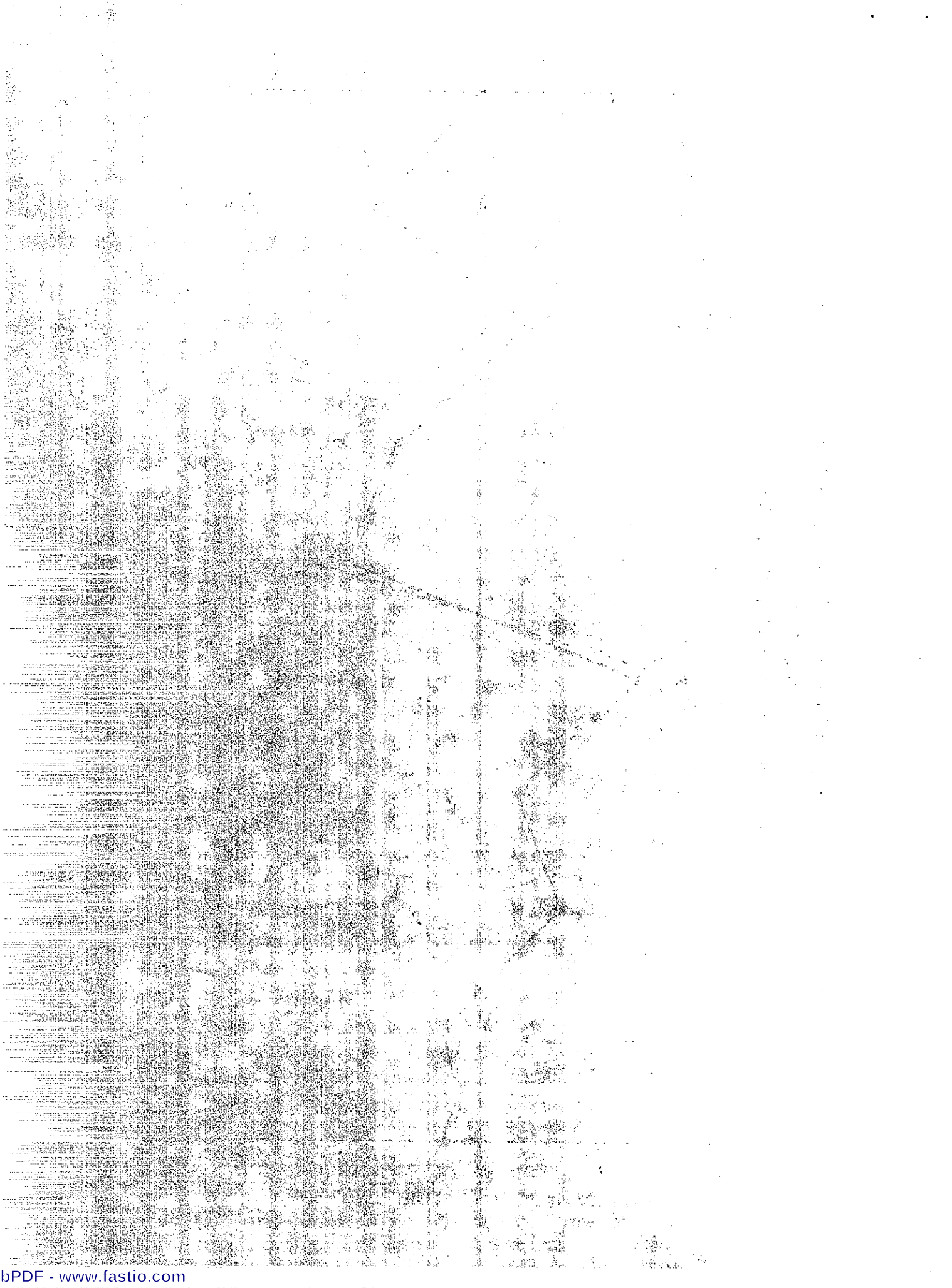
* Sherman, G. B., Watkins, R. O., Prysock, R. H., " A Statistical Analysis of Embankment Construction", Presented at 46th meeting of HRB, Jan. 1967, No. M&R 631133-3

However, in order to eliminate any controversy over the site selection process between the Engineers and the Contractors, a modified random method of site selection should be used. The inclusion of a modified random sampling procedure would also serve to make the area concept test method more nearly correct from a theoretical and practical standpoint.

It was believed that a pure random sampling was too complex and impractical for a field test. Therefore, a modified random sampling plan was developed and adopted.

Figure 1





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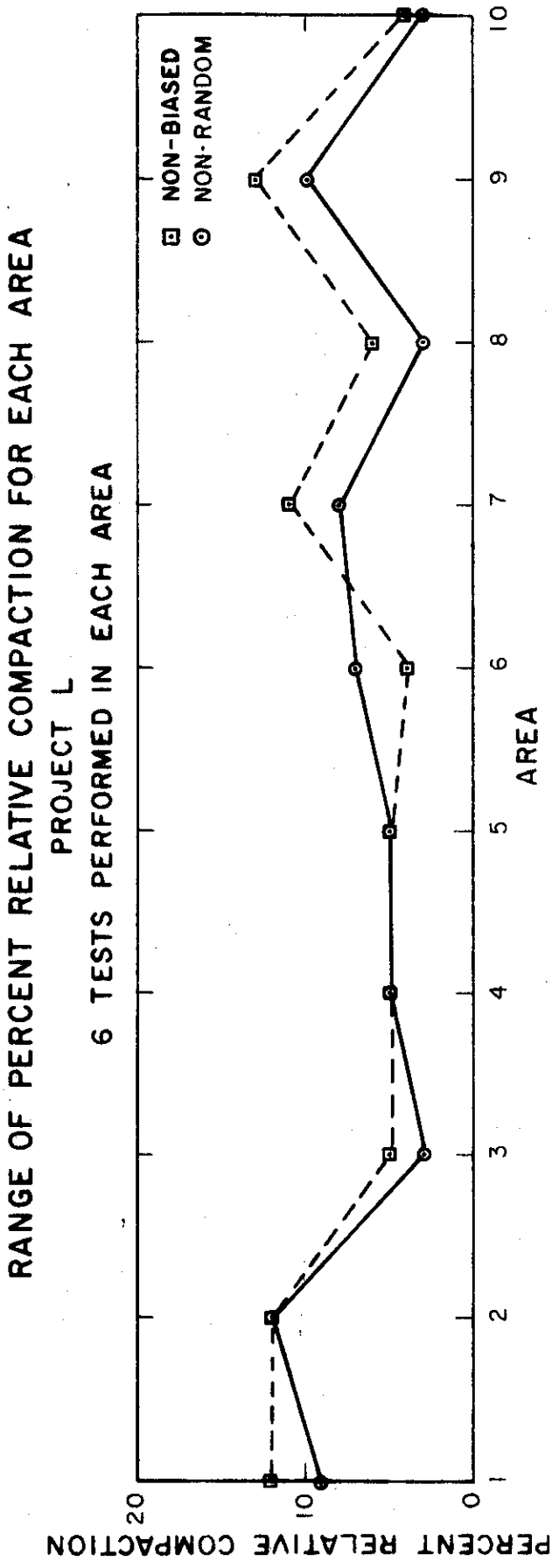

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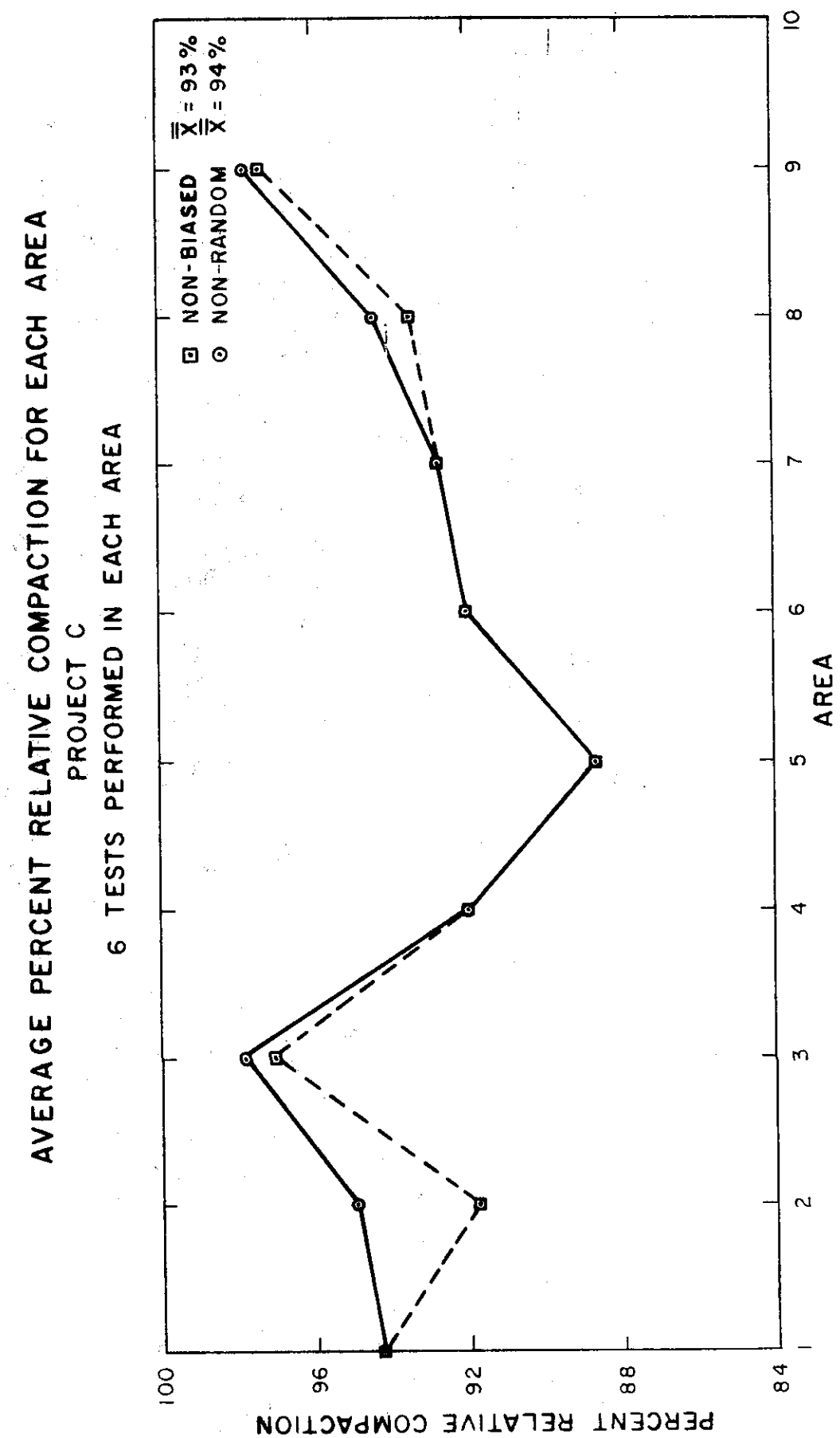


Figure 4

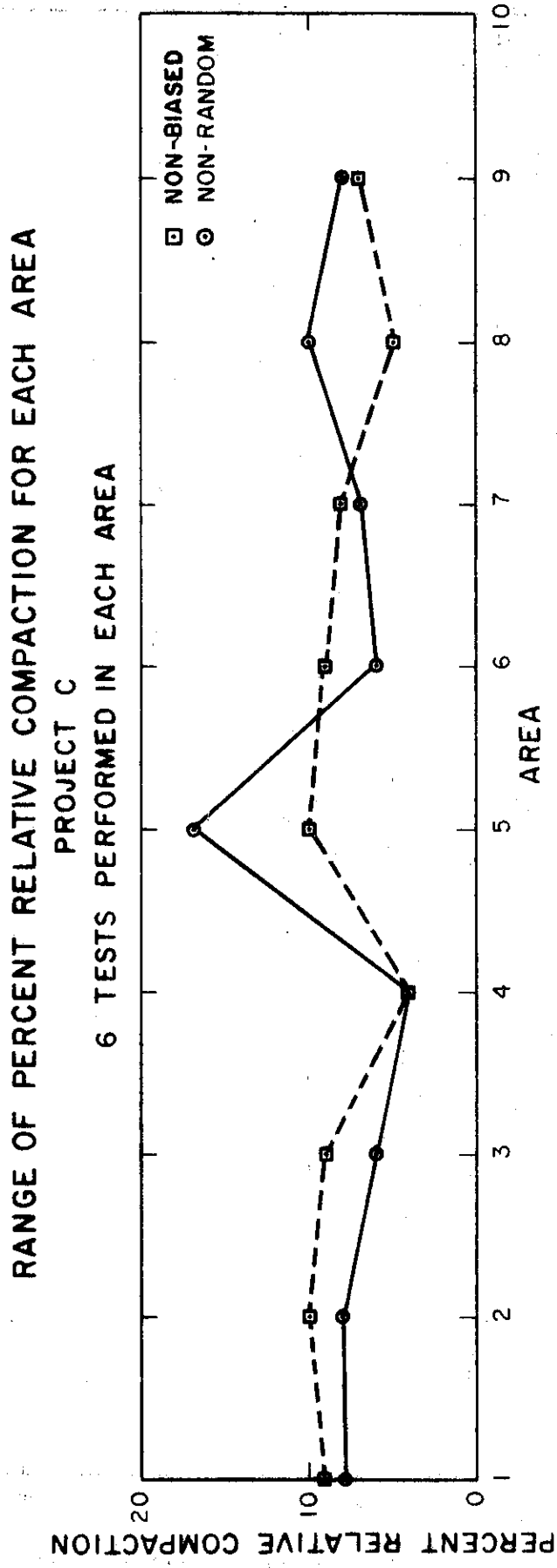


Figure 5

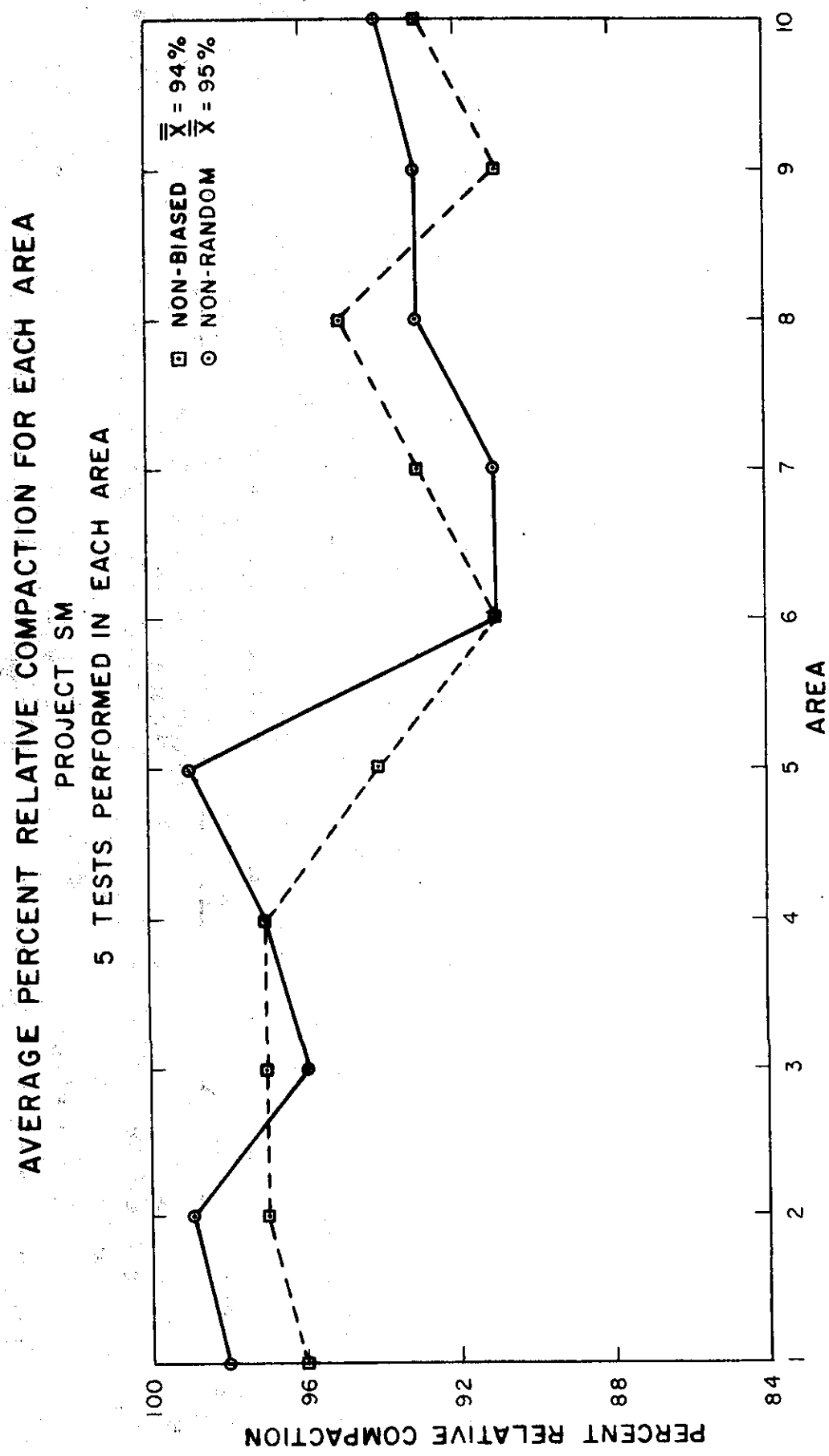


Figure 6

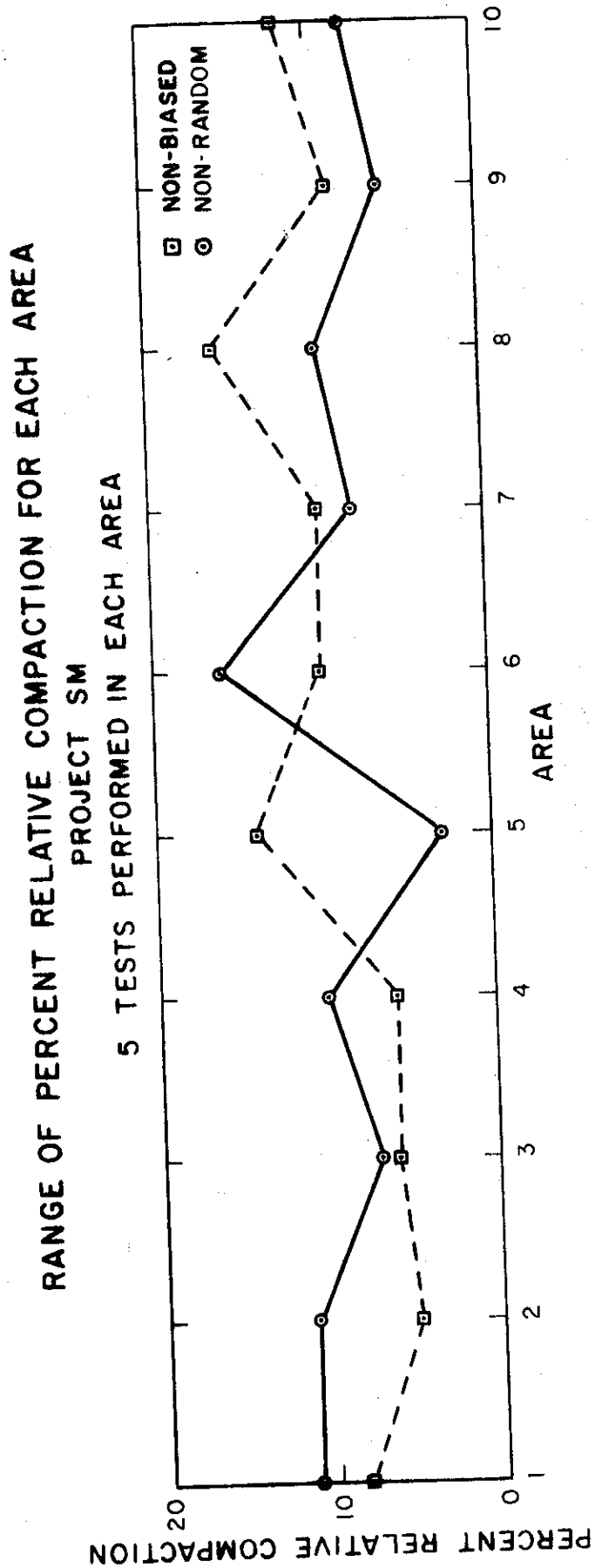


Figure 7

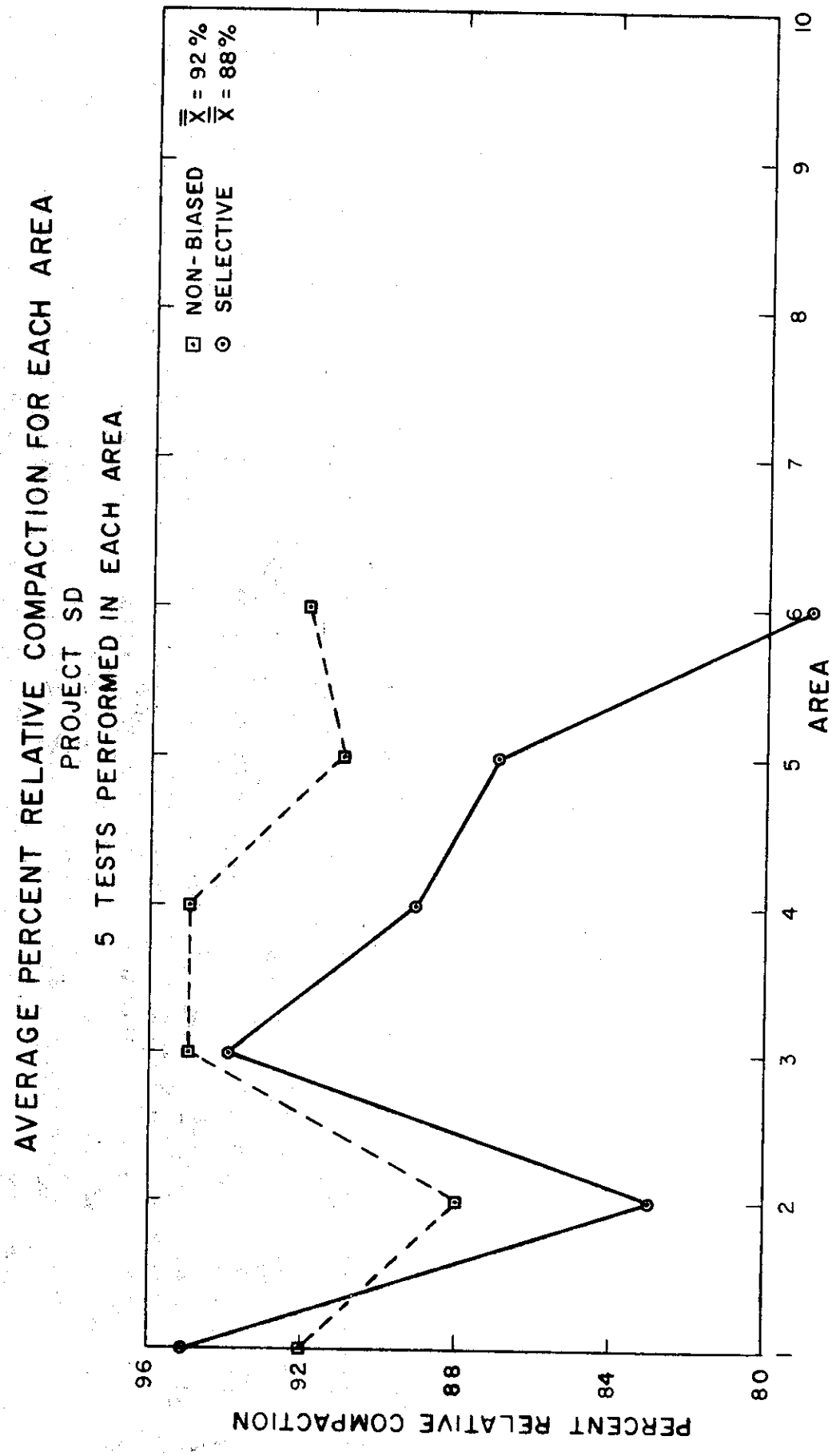
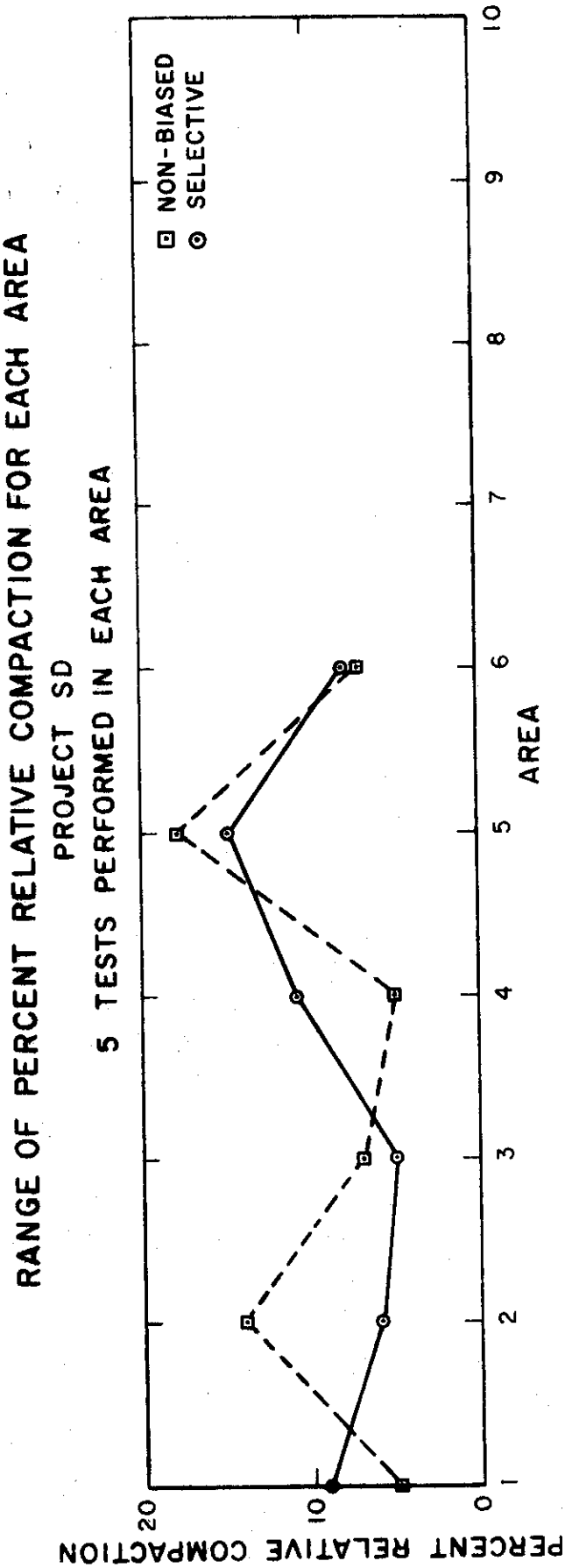


Figure 8



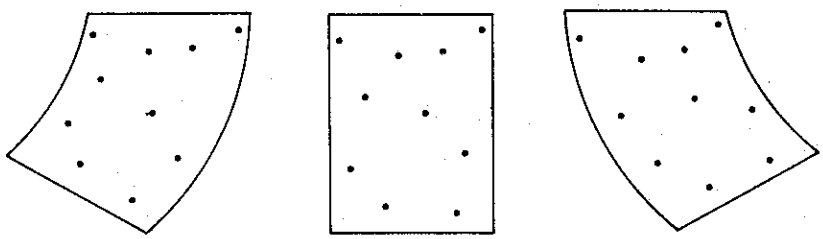
Appendix I

NONBIASED SAMPLE PLANS

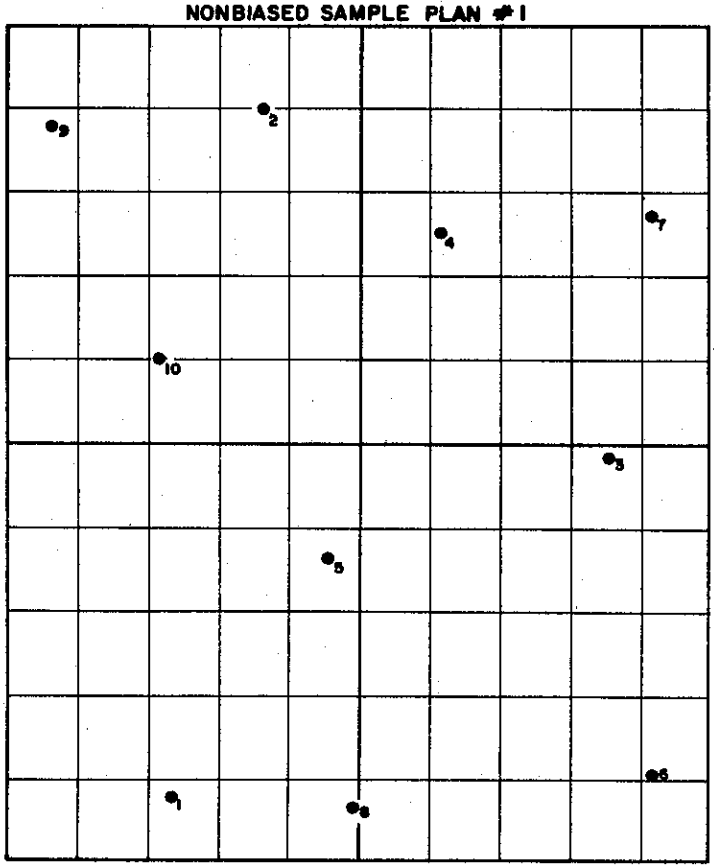
Once an area is selected on the basis of uniformity of factors, nonbiased location of measurement sites is required for applying statistical control procedures. The nonbiased sample location plans will randomly locate the approximate measurement sites. Note: The number of measurement sites must be determined after the area has been determined and before any tests performed.

PROCEDURE FOR USE OF
NONBIASED SAMPLE PLANS

1. Use the last digit from the first reading taken for the daily standard count to select the plan for the first area. For subsequent areas use the last digit from the second, third, fourth, and fifth readings. If six through ten areas are tested, use the second to the last digit from the first through the fifth readings taken for the daily standard count.
2. Visualize the plan as a map of the area to be sampled.
3. Each dot represents a measurement site. There are 10 dots numbered from one (1) through ten (10). If you are to take a five (5) site test then use the dots numbered from one (1) through five (5). If a three site test is going to be used then use the locations of the first three dots. This procedure will be used for all tests, with number 1 dot the first site, number 2 dot the second site and so on until the desired number of sites have been used.
4. Test at the approximate locations on the grade represented by the dots on the plan. Some adjustments are necessary for irregular areas.



NONBIASED SAMPLE PLAN #1



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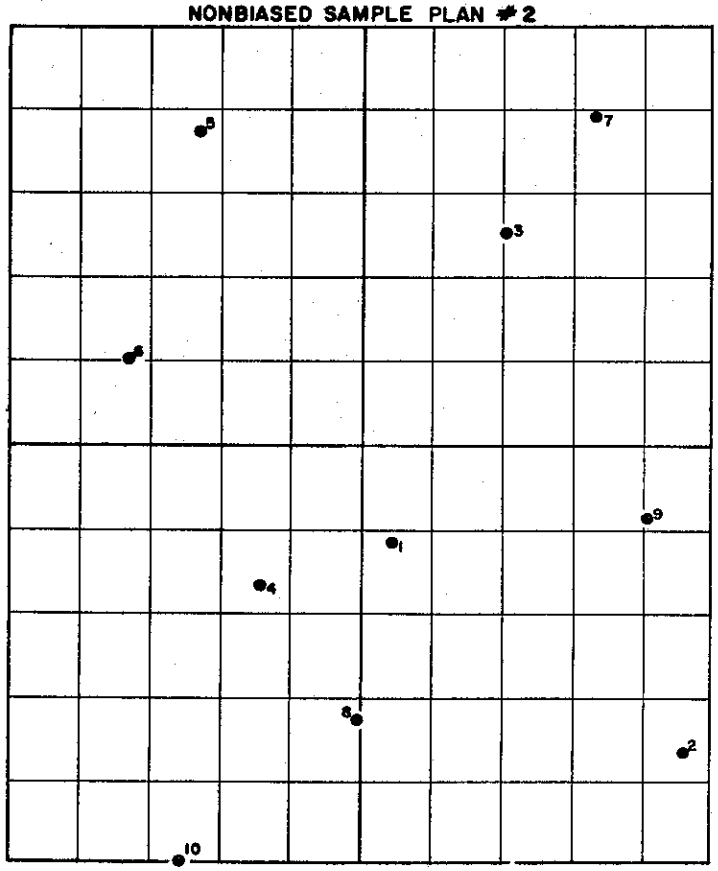

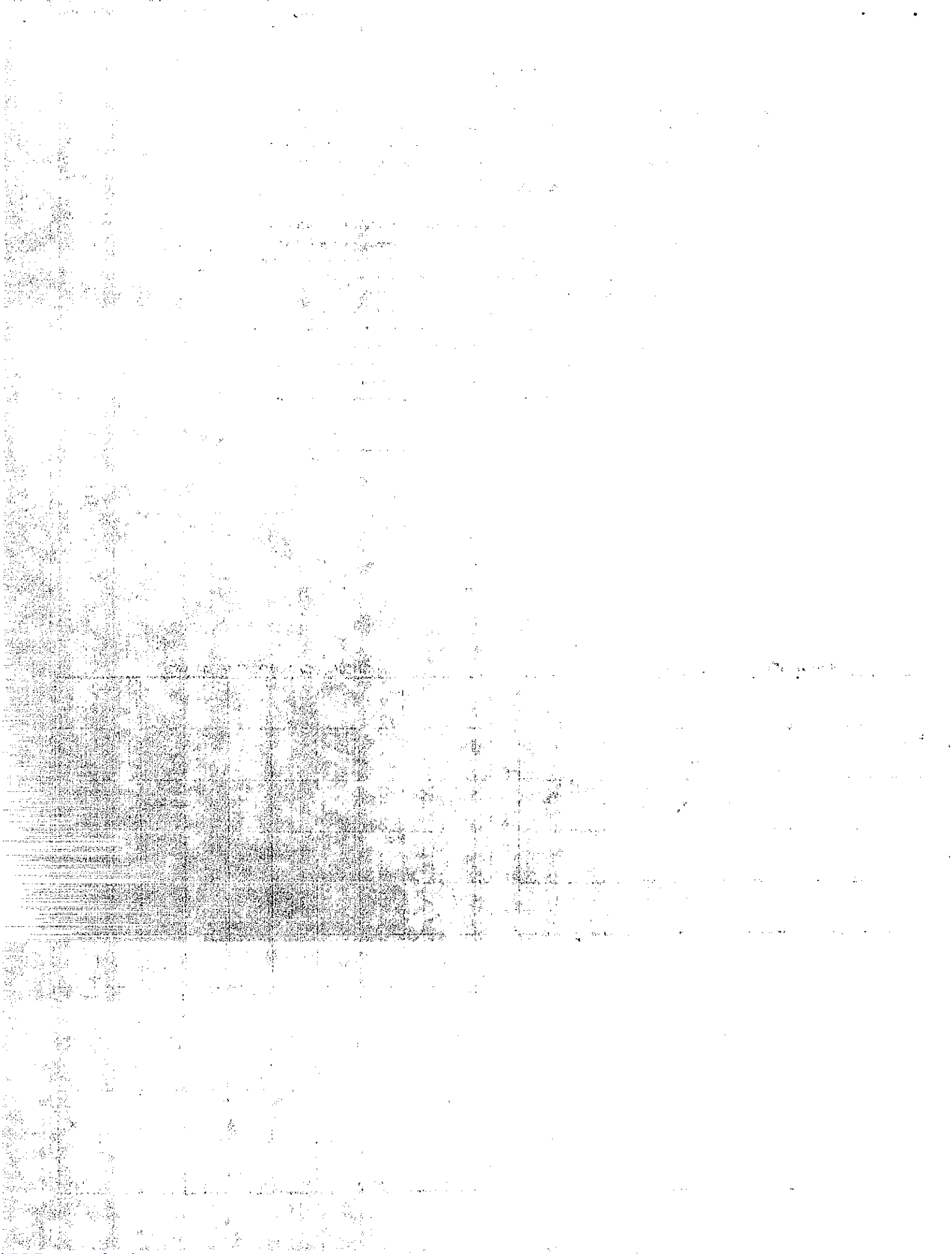

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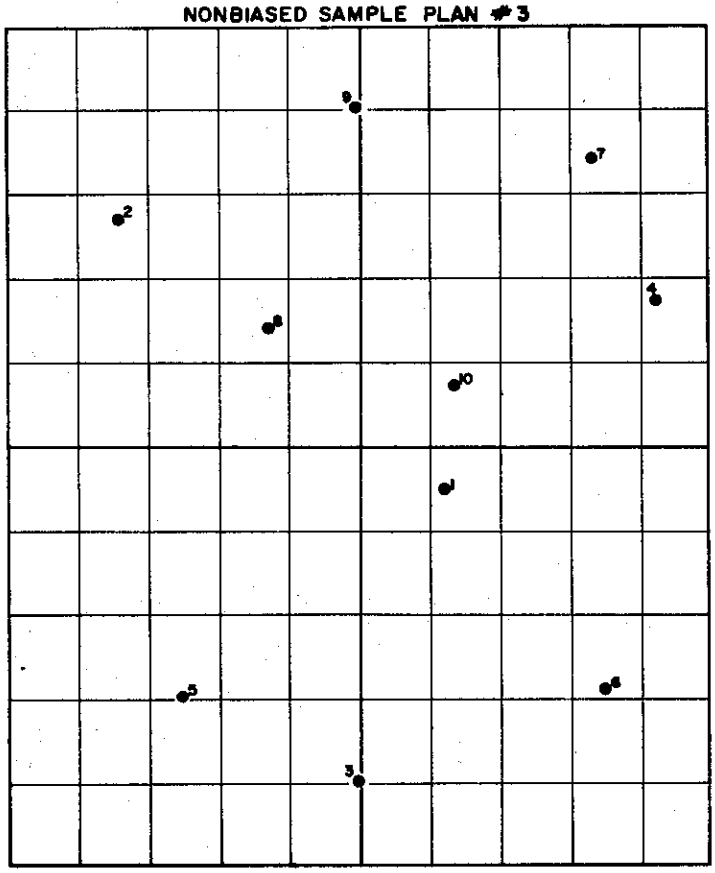

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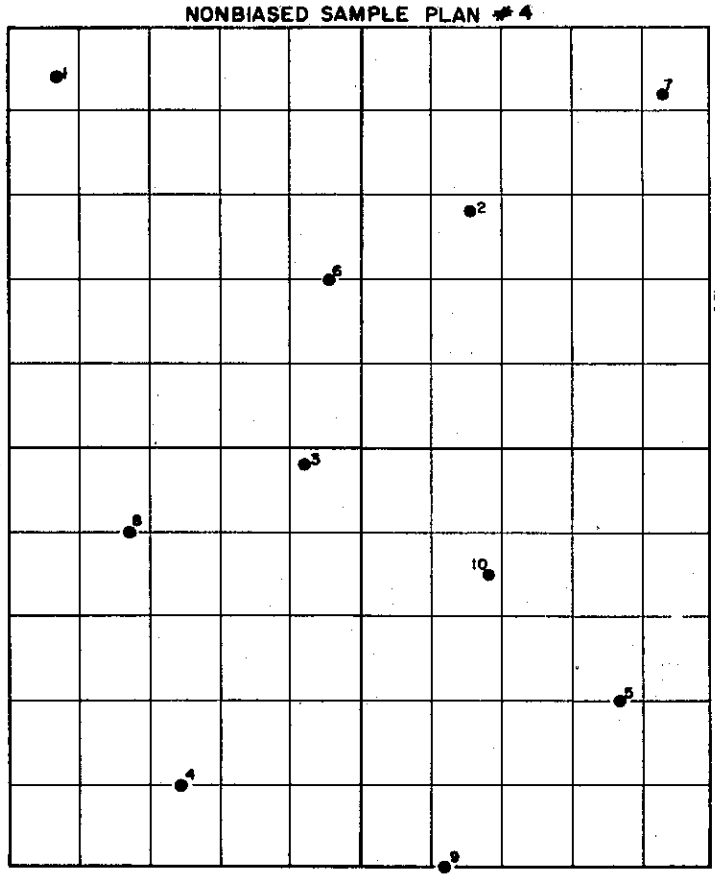

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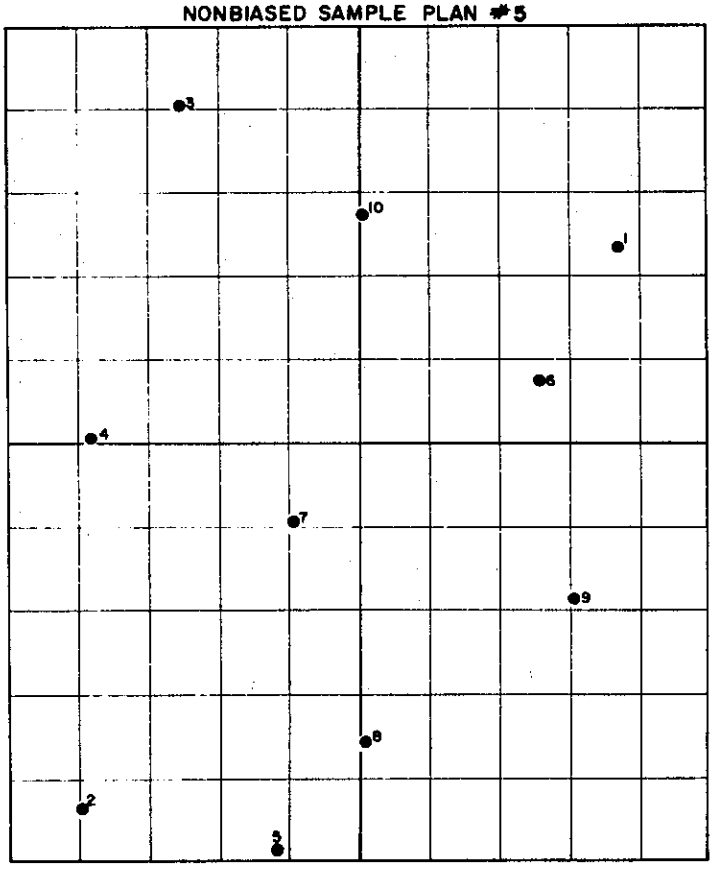

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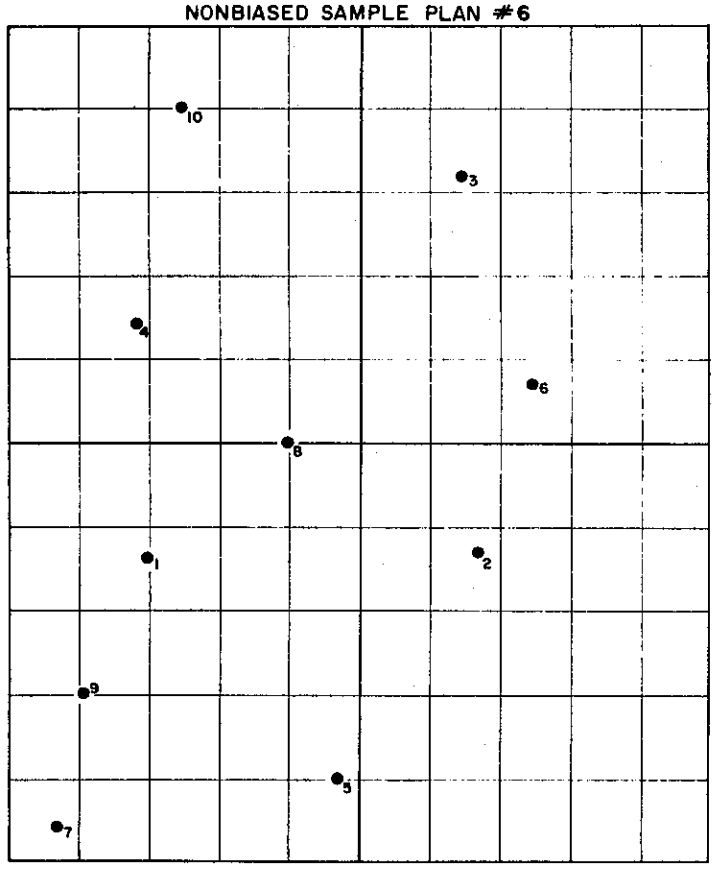

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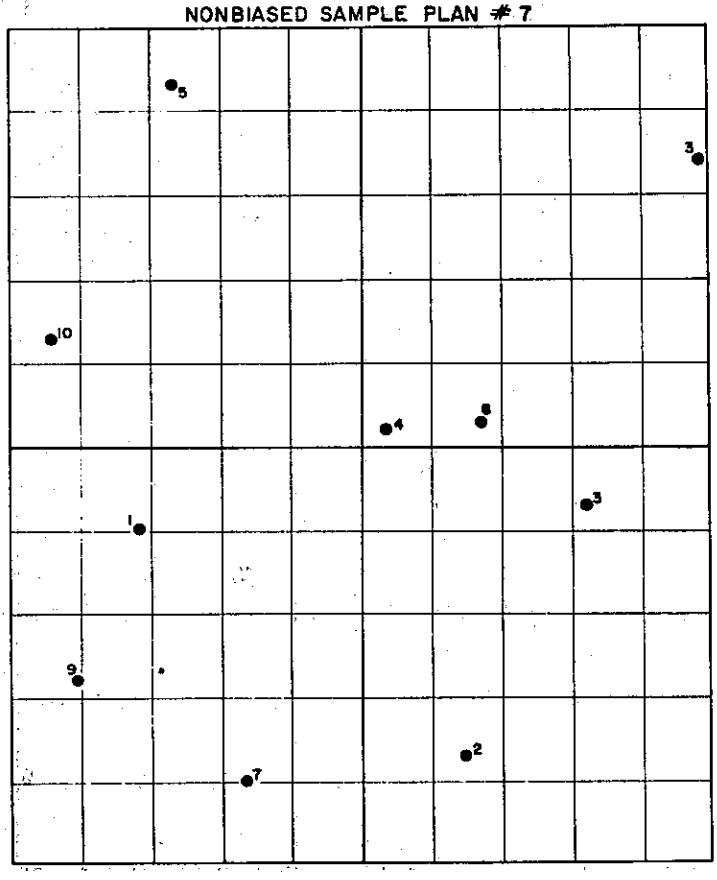

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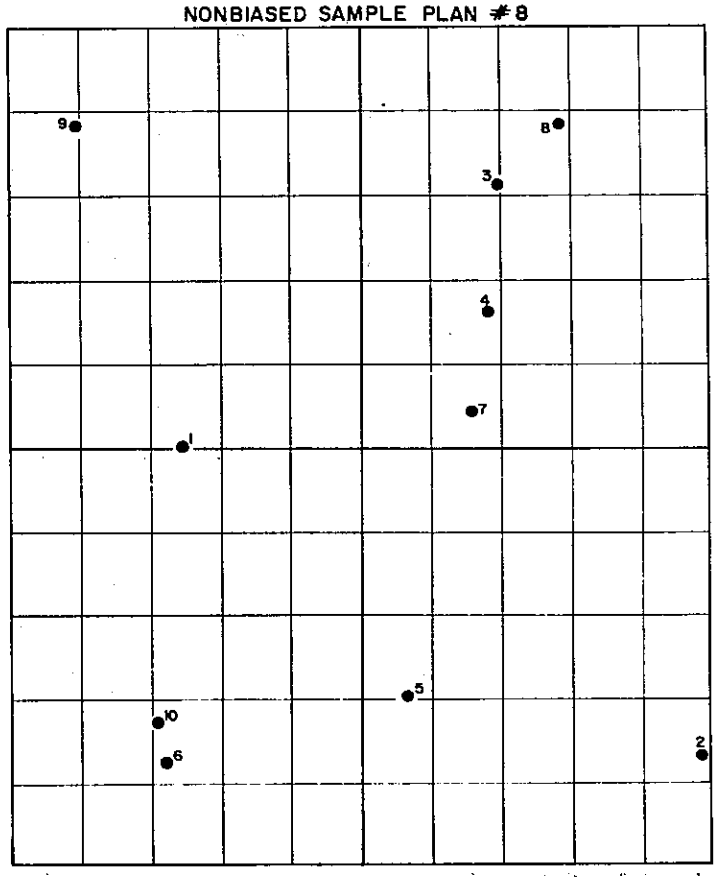

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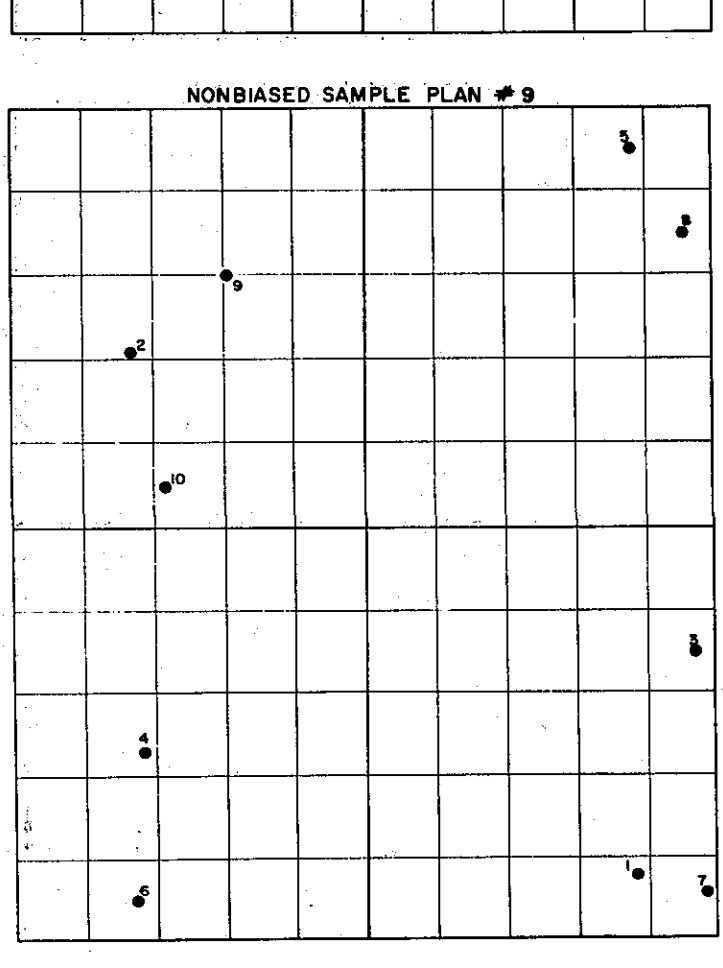

NONBIASED SAMPLE PLAN #10